MECH 575
Introduction to Hydrodynamic Stability
Spring 2019

Introduction to linear and nonlinear instabilities that cause transition from laminar to turbulent flows in thermo-fluid systems. The physics of various canonical instability mechanisms and the mathematical and numerical frameworks common in stability analysis are discussed. Examples from industrial, geophysical, environmental, and astrophysical flows are presented.

Instructor:

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Office Hours

Thursdays 11am-12pm, MEB 222

Class:

Hours: TR 9:25am-10:40am
Room: MEL 254

Pre-requisites:

Undergraduate fluid mechanics and applied math (especially linear algebra, differential equations, and Fourier analysis). Familiarity with basic programming in MATLAB (or another programming language) and elementary concepts of numerical analysis.

Grading:

Homework (15%): Three problem sets consisting of analytical and numerical problems
Midterm (35%): Take-home exam
Presentation (50%): A critical evaluation of three published papers on a stability problem

Textbooks:

- P. K. Kundu and I. M. Cohen, Fluid mechanics, Academic Press
  Available online via Rice network: http://www.sciencedirect.com/science/book/9780123821003
- P. G. Drazin, Introduction to hydrodynamic stability, Cambridge University Press

Other suggested resources:

- P. G. Drazin and W. H. Reid, Hydrodynamic stability, Cambridge University Press
- P. J. Schmid and D. S. Henningson, Stability and transition in shear flows, Springer
- W. O. Criminale, T. L. Jackson, R. D. Joslin, Theory and computation of hydrodynamic stability, Cambridge University Press

All books are on reserve at Fondren Library (Kundu's book is also available online)

Notice:

Any student with a disability requiring accommodation in this course is encouraged to contact the instructor as soon as possible. Also these students should contact Disability Support Services in the Ley Student Center.

Honor Code:

Students must abide by the Honor Code on the take-home exam and the homework assignments. You can use the class notes, your graded homework assignments, and the textbook and suggested books for the take-home exam. You cannot use any other resource (e.g. journal or conference papers, other books, internet etc.) for the take-home exam. Collaboration/discussion is not allowed on the take-home exam. You can discuss the homework problems with your classmates and consult any book when working on the homework problems; however, the submitted work must be entirely yours and you should not copy solutions/results from others.

Tentative Outline:

Note: Sections/Chapters are from the version of Kundu that is available online

Lecture	Topic	Optional reading
Lecture 1: Jan. 8	Fundamental concept of fluid (in)stability; some examples and applications	Kundu: 4.1-4.6, 4.8 Kundu: 11.1
Lecture 2: Jan. 10	Equations of motion for fluid flows; Navier-Stokes and Boussinesq equations; Some analytical solutions	Kundu: 8.1-8.2 & 4.10
Lecture 3: Jan. 15	Equations for perturbations; non-dimensionalization; example: Rayleigh-Benard problem	Kundu: 4.11 & 11.4
Lecture 4: Jan. 17	Continuing Lecture 3; Linearization; example: Couette problem	Drazin: 6.1-6.2
Lecture 5: Jan. 22	More on Couette problem; Modal analysis *End of the review period*	Kundu: 11.2
Lecture 6: Jan. 24	Rayleigh-Benard instability	Kundu: 11.4
Lecture 7: Jan. 29	Rayleigh-Benard instability Homework #1 posted	Drazin: 6.1-6.3
Lecture 8: Jan. 31	Centrifugal instability (Taylor-Couette flow)	Kundu: 11.6
Lecture 9: Feb. 5	Centrifugal instability (Taylor-Couette flow)	Drazin: 7.1-7.3
Feb. 7	*No class (recess)*	
Lecture 10: Feb. 12	Numerical stability analysis	
Lecture 11: Feb. 14	Kelvin-Helmholtz instability Deadline: Homework #1	Kundu 6.1-6.2 Kundu 11.3
Lecture 12: Feb. 19	Kelvin-Helmholtz instability Homework #2 posted	Drazin: 3.1-3.8
Lecture 13: Feb. 21	Kelvin-Helmholtz instability	Kundu 11.7-11.10
Lecture 14: Feb. 26	Stability of parallel flows	Drazin 8.1-8.3
Lecture 15: Feb. 28	Stability of parallel flows	Drazin 8.5-8.7
Lecture 16: March 5	Stability of boundary layers	
Lecture 16: March 7	Stability of boundary layers Deadline: Homework #2	
March 12 March 14	*No class (spring break)*	Prepare for midterm

Lecture 17: March 19	Stability of boundary layers Posted: Take-home midterm	Kundu 11.11
Lecture 18: March 21	Zombie vortex instability Deadline: Take-home midterm	Drazin 8.10
Lecture 19: March 26	Crow instability Homework #3 posted	
Lecture 20: March 28	Baroclinic instability	Kundu 14.17
Lecture 21: April 2	Baroclinic instability *End of the modal linear stability analysis*	Kundu 14.17
Lecture 21: April 4	Non-normal growth and non-modal analysis *End of linear stability analysis* Deadline: one-page summary of the presentation	Trefethen's notes
Lecture 22: April 9	Nonlinear stability and Transition to chaos	Kundu 11.2-11.13
Lecture 23: April 13	Nonlinear stability and Transition to chaos	Kundu 11.2-11.13
April 16	Project Presentations	
April 20	Project Presentations Deadline: Homework #3	